

Pre-drill pore pressure prediction using seismic velocities data on flank and synclinal part of Atharamura anticline in the Eastern Tripura, India

Jwngsar Brahma · Anirbid Sircar · G. P. Karmakar

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Abstract The Tripura state went through extensive geological tectonics that resulted in the creation of complex structural styles with different fault types, lineaments, and plate boundaries, which in turn caused possible zones with over-pressured formations characterized by higher seismic amplitude signatures. Without accurate estimates of pore pressures, drilling through these hazardous zones is very troublesome and could jeopardize the whole drilling rig site. Pore pressures are easily predicted for sediments with normal pressure gradient. The prediction of pore pressure for the abnormally pressured (i.e., overpressured) sediments is more difficult and more important. Understanding of the pore pressure is a requirement of the drilling plan in order to design a proper casing program. With balanced drilling mud, overpressured formations, and borehole instability will be effectively controlled while drilling and completing the well. Well control events such as formation fluid kicks, loss of mud circulation, surface blowouts, and subsurface kicks can be avoided with the use of accurate pore pressure and fracture gradient predictions in the design process. In this study, transform models using modified Eaton's method were used to predict pore pressures from seismic interval velocities. Corrected two-way travel times and average velocity values for 28 sorted common depth points were input into the transform for pore pressures prediction. Predicted pore pressures show a reasonable

match when plotted against formation pressure data from the offset wells namely AD-4 trend, Agartala Dome-6, Ambasa trend, Kathalchari trend, Kubal, Masimpur-3, Rokhia structure-RO1, and Tichna structure-TI1. In this study, it is observed that overpressure starts at shallow depths (1,482–2,145 m) in synclinal section while in flank section it starts deeper (2,653–5,919 m) in Atharamura anticline. It is also observed that the most of wells showing pressure match are located in the western side of the Atharamura. The maximum predicted pore pressure gradient observed in this study is 1.03 psi/feet in both synclinal and flank sections of Atharamura anticline. Based on our observations, it is interpreted that Tripura region is characterized by single pressure source and the pressure is distributed evenly in all the anticlines in this region.

Keywords Middle Bhuban · Atharamura Anticline · Seismic velocities · Pore pressure · Offset well

Introduction

A pre-drill prediction of pore pressure is an integral part of the well planning and formation evaluation process. An accurate estimation of formation pore pressure is a key requirement for safe and economic drilling in overpressured sediments. Pore pressure within formations determines the mud weight required to build a balancing fluid pressure in the downhole. An improper understanding of the subsurface geology and the formation pressures may result in fracturing the formation if the mud weight is too high. In contrast, if mud weight is too low, then the formation fluids can flow into well, potentially leading to well blowouts if not controlled. High pore pressures or overpressures have been observed at drilling sites all over the

J. Brahma (✉) · A. Sircar · G. P. Karmakar
Pandit Deendayal Petroleum University, Raisan Village,
Gandhinagar 382007, Gujarat, India
e-mail: jwngsar@gmail.com

A. Sircar
e-mail: anirbid.sircar@spt.pdpu.ac.in

G. P. Karmakar
e-mail: gp.karmakar@spt.pdpu.ac.in

world, in both land and offshore. The frequently encountered overpressures in the Gulf of Mexico have been particularly well studied and observed since it is an important area of hydrocarbon production. The phenomenon has been observed in many other places, including North Sea, Caspian Sea, Pakistan and the Middle East, eastern parts of India. The nature and origin of pore pressures are manifold and complex. The demands for better understanding and pre-drill prediction of pore pressure are substantial. To estimate the abnormal pressures first, it is important to understand the pore pressure concepts and under what conditions it becomes abnormal. In this paper, pore pressures were estimated from seismic velocities using an appropriate model for velocity to pore pressure transform (Bowers 1995; Hottman and Johnson 1965; Dutta 1997). Pre-drill pore pressure has been obtained from transform model using seismic interval velocity. The transformation model (seismic interval velocity to pore pressure transform) is shown in the Fig. 1 but the accuracy of pore pressure prediction depends on the estimation accuracy of seismic interval velocities. The seismic interval velocities were estimated from two-way seismic root mean square (RMS) velocities by Dix equation (Dix 1955). During seismic processing, seismic velocities used are designed in such a way that the stack/migration is optimum with local fluctuations being smoothed out and the velocity pick interval usually being too coarse for accurate pore pressure prediction.

Pore pressure or formation pressure is the pressure experienced by the pore fluids in the pore space of subsurface formations. Knowledge of expected pore pressure and fracture gradients provide valuable information for efficiently drilling wells with optimum mud weights, casing point selection, and for proper completions. Formation pressures influence compressibility and the failure of

reservoir rocks. Furthermore, it allows the identification of the effectiveness of seals and system hydraulic connectivity. To understand the possible cause of abnormal formation pressures, it is essential to understand the importance of petrophysical and geochemical parameters and their relationship to the structural and tectonic history of a given area. Before drilling, pore pressure is estimated based on pore pressure data from offset wells in the area. However, subsurface conditions can vary widely from well-known area to an area of similar conditions in a nearby basin. Pore pressure can also be estimated from logging while drilling data such as resistivity measurements using various methods. Pore pressure data is needed to calibrate the results.

In normal pressured formations, porosity decreases with depth as the pore fluids are expelled out of pores due to the increasing overburden weight. Thus, this pore fluid expulsion maintains the effective communication of pore fluids with the surface. So, at any depth pore pressure is simply the same as the hydrostatic pressure (1.03 g/cm^3 or 0.433 psi/foot) of the water column. In other words, pore pressure in normal compacted sediments is entirely due to the density and height of the fluid column. In abnormal overpressured formations, the pore water expulsion is intercepted by rapid sedimentation and the absence of permeable pore networks. Thus, when the pore fluid experiences pressure above the normal hydrostatic pressure (1.03 g/cm^3 or 0.433 psi/foot), overpressure or super pressure develops (Bourgoynne 1991). In other words, the moment the pore fluid starts bearing the weight of the overlying sediments overpressure develops.

In the absence of well data, seismic velocities are the only available pre-drill tools to estimate the formation pressures. Though the pore pressure prediction has the history of five decades, preciseness of wildcat pore pressure predictions are still in wide range of uncertainty. Pore pressure prediction in geologically challenging areas such as anticlines and fold thrust faults combined with possibility of abnormal pressures elevates this prediction to a high level of uncertainty (Swarbick Richard et al. 1999). This paper discusses pre-drill pore pressure prediction from seismic velocities for safe wildcat well planning.

As the Atharamura stratigraphy thickness is not well known, bulk density of the formation was calculated using the values of $\Delta t_{\text{max}} = 62.5 \text{ } \mu\text{s/foot}$ (for shale, $\Delta t_f = 200 \text{ } \mu\text{s/foot}$) (for water) in the Eq. 2.

In this study, the repeat formation tester (RFT) data were collected from nearby offset wells, namely AD-4 trend, Agartala Dome-6. Ambasa trend, Kathalchari trend, Kubal, Masimpur-3, Rokhia structure-RO1, and Tichna structure-TI1 to estimate reliable surface fluid flow as well as to get better understanding of the pore pressure succession in this region. The predicted pore pressure values at common depth points (CDPs) are compared with pore pressure measured by RFT from these drilled offset wells.

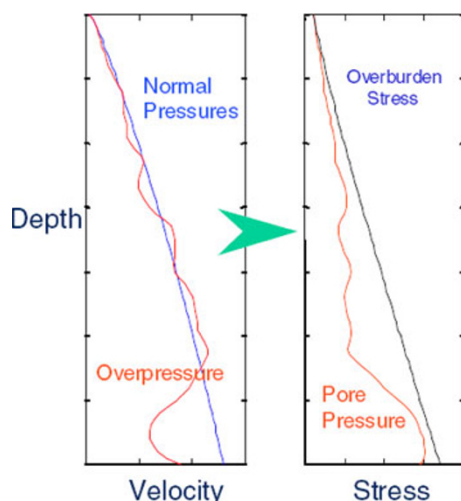


Fig. 1 Transform model for pre-drill pore pressure prediction (seismic interval velocity to pore pressure transforms)

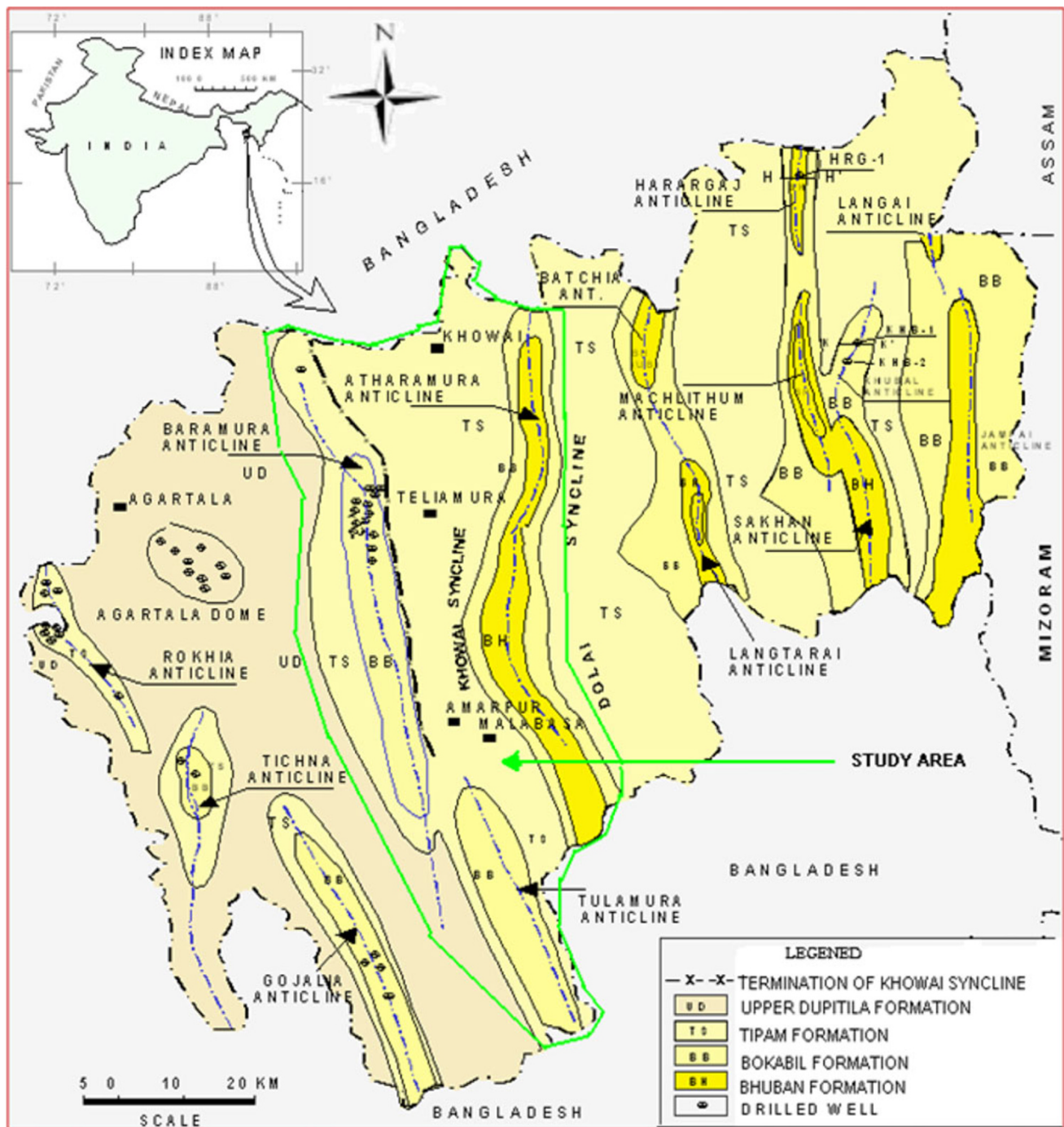


Fig. 2 Anticlines and synclines in and round Atharamura, Baramur, and Tulumura anticlines. Map depicts the structural position of the study area (Ganguly 1983)

Geologic and structural settings

The Tripura region is situated in the north-eastern sector of India, and is surrounded by the territories of Bangladesh and Burma, except in the north-eastern part, which is bordered by the Indian states of Assam and Manipur (Fig. 2). Geographically, it is bounded by the latitudes 22°00′N and 24°30′N and the longitudes 91°10′E and

93°30′E. Geomorphologically, this region is characterized by an alternating succession of ridges and valleys of roughly north-south trend. The general elevation of the region rises eastward from few tens of meters in the area adjoining Bangladesh plains in western Tripura to about 1,800 m in eastern Mizoram bordering the Chin Hills of Burma.

The sedimentation in this basin probably started with a breakup of the Gondwana land in Jurassic and Cretaceous

and had been almost continuous since then. The Palaeocene Eocene Disang formation forms the base overlain by rocks of the Barail group which is divided into Lisang followed by Jenam and Renji formation. The overlain Miocene Surma group is made up of lower, middle and upper Bhuban formations with Bokabil formation occupying the topmost part. The Tipam, Dupitila, Disang formations constitute the upper Neogene units. The aerial gravity survey leads to the delineation of 14 large closed anticlinal structures, comprising thick deltaic sedimentary succession of Neogene age with favorable geological prospect, viz., Rokhia, Tichna, Gojalia, Baramura, Tulamura, Atharamura, Batchia, Langtarai, Harargaj, Machlithum, Khubal, Skham, Langai, and Jampai anticlines (Fig. 3). In addition, a buried dome structure was suspected on the basis of geomorphological features in the wide synclinal trough between Rikhia and Baramura anticlines and this has later been confirmed by seismic survey and named as Agartala Dome. A series of long and narrow anticlines with north-south trending axial traces separated by broad intervening synclines are present in Tripura fold belt thrust (FBT). Some of these anticlines show en echelon offsets. In most of the anticlines middle Bhuban formation is capped by upper Bhuban, Bokabil, and Tipam formations (Fig. 4). High abnormal to super pressures are observed from middle-lower Bhuban, practically in all the structures of the Cachar area with pressure gradient reaching to almost geostatic or even exceeding it. Compaction disequilibrium, aided partly by clay diagenesis and tectonic activity, has been found responsible for generation of overpressures in Tripura area (Sahay et al. 1998).

From the past, well-drilled data in the Tripura region, supper pressure regime below the middle Bhuban is confirmed, but not a single well is drilled in the deeper depths of the middle Bhuban due to well control problems. Unlike other anticlines, in Atharamura anticline middle Bhuban is exposed to the surface and increases the possibilities of overpressure at the shallow depth.

Methodology

In the lack of pore pressure data in the study area, we utilize seismic velocities as reasonable alternative for formation pore pressure prediction. The seismic velocity analysis in the reflection wave method has been traditionally applied for the pre-drill prediction of subsurface overpressure formations since the early 1960s. The location of the first successful implementations was the Gulf of Mexico, where thick Pleistocene–Miocene sediments are represented by clastic rock, which are poorly consolidated at the upper section and are often overpressured from the very top.

In order to obtain an estimation of the pore pressure from seismic velocities, one must know how the velocities are influenced by pore pressure. Pore pressure estimation from seismic velocity data is a multidisciplinary subject that requires thorough knowledge of seismic data processing as well as an understanding of rock physics. The key parameters for pore pressure prediction are P-wave (V_p) and S-wave (V_s) velocities. All methods take advantage of the fact that sonic velocities depend on the effective pressure, and hence the pore pressure.

The relation between effective pressure and velocity depends heavily on the texture and mineral composition of the rock. For instance, for unconsolidated sandstones, the P-wave velocities vary significantly with effective pressure (Domenico 1977). The mechanism thought to be important here is the strengthening of grain contacts with increasing effective pressure. When applying external load to unconsolidated sand, the contact between the individual grains becomes stronger. Thus, the stiffness of the sand is increased. This leads to an increase in P-wave velocity. Mostly, overpressured zones are caused by undercompaction in which porosity is abnormally high with depth. Thus, this leads to reduction in seismic wave velocity and hence an increase in acoustic impedance.

As per Hottman and Johnson (1965), empirical correlation of velocity ratios versus expected pressure gradient or mud weight is essential for the quantitative pore pressure evaluation. In all velocity-based methods, developmental of normal compaction curves plays critical role in overpressure estimations and limits the uncertainty of the prediction. Hottman and Johnson method work well where the offset well data is readily available, but in the wildcat planning the development of normal compaction will determine the uncertainty in pore pressure estimation.

Hydrostatic pressure is defined as the pressure exerted by a column of water at any given point in that column, when water is at rest. It is the pressure due to the density and vertical height of the column which exerts force in all directions perpendicular to the contacting surface (Bourgoyne 1991). Mathematically, it can be expressed as a product of fluid density, height of the fluid column, and acceleration due to gravity.

Overpressure, on the other hand, is caused by undercompaction, fluid volume increase, fluid migration and buoyancy, and tectonics (Swarbick Richard et al. 1999). Compaction is a process associated with sedimentation. When the deposition occurs, grains support the weight of overlying sediments due to point to point contact between the grains. As deposition proceeds fluid trapped in the pore spaces escapes and porosity reduces to balance the overburden weight so as to maintain the normal hydrostatic pore pressure. When this equilibrium (pore water expulsion) is disturbed by the rapid sedimentation (Rubey 1927)

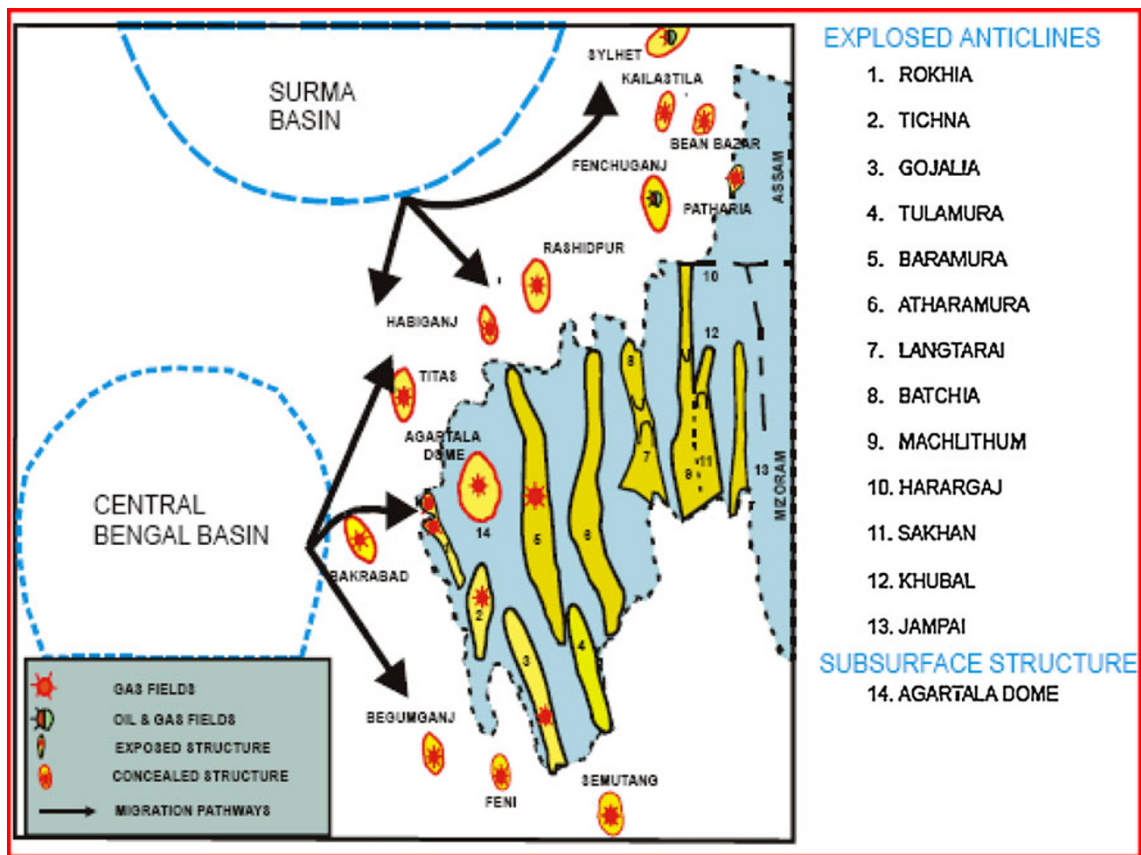


Fig. 3 A series of anticlines of Tripura region (Jena et al. 2011)

or absence of permeable pore networks, abnormal or overpressure occurs. This change in normal trend is called undercompaction or compaction disequilibrium. This is the dominant overpressure causing mechanisms in shallow depth.

Formation pressure is the pressure acting upon the fluids in the pore space of the formation. In a normally pressured geologic setting, the formation pressure will equal the hydrostatic pressure. Any deviation from the normal trend line, abnormal formation pressure occurs.

From among the available methods Bowers (1995) and Eaton's (1975) methods predictions are well known for their accuracy. But the real constraint in the selection of prediction method is availability of data. As the Tripura sub-basin is starving of extensive exploration work, offset well data requiring for the Bower's method are readily not available. So here modified Eaton's method is used to predict pore pressure and the predictions are compared with offset well measured pore pressures.

By the time-depth conversions (Pennebaker 1968), formations depths having different acoustic impedance can be found. From the interval travel time data, formation interval density was found by the following formula (ENI 1999).

In terms of interval velocity

$$\rho_{b,i} = \rho_{\max} - 2.11 \left[\frac{1 - \frac{v_{\text{int},i}}{v_{\text{max}}}}{1 + \frac{v_{\text{int},i}}{v_{\text{max}}}} \right] \quad (1)$$

In terms of interval transit time

$$\rho_{b,i} = \rho_{\max} - 2.11 \left[\frac{\Delta t_{\text{int}} - \Delta t_{\text{max}}}{\Delta t_{\text{int}} + \Delta t_f} \right] \quad (2)$$

where

$v_{\text{int}}, v_{\text{max}}$

= interval and matrix velocities of the formation (m/s).

$\Delta t_{\text{max}}, \Delta t_f$ are interval transit time in rock matrix and fluid ($\mu\text{s}/\text{feet}$). Then the overburden pressure is calculated simply by the following equation:

$$P_{\text{ob}} = \sum_{i=1}^N P_{\text{ob},i} = \int \rho_{b,i} dD \quad (3)$$

The development of normal compaction parameters plays a vital role in determining the reliability of the pore pressure prediction. Notable pore pressure prediction methods are Hottman and Johnson, equivalent depth

AGE		FORMATION	LITHOLOGY	EOD	PETROLEUM SYSTEM
RECENT		ALLUVIUM			
PLIESTOCENE					
PLIOCENE	L	AGARTALA			
	E	MAHES TRAM		FLUVIAL BED	
MIOCENE	L	BOKABIL 1000 m		MARINE DELTA (TIDAL), SHALLO W & DEEP MARINE	C CAP ROCKS
	M	UPPER BHUBAN 1000 m			SHALES WITH IN BHUBAN & BOKABIL FORMATION
	E	MIDDLE BHUBAN 700 m		DEEP MARINE SHALLOW MARINE & MARINE DELTA (TIDAL)	R RESERVOIR ROCKS
		LOWER BHUBAN 1000 m			RENGI, BHUBAN & BOKABIL SANDSTONES
		RENGI 700-1000 m		MARINE DELTA, SHALLOW & DEEP MARINE	OLIGOCENE BARAIL SANDSTONES
OLIGOCENE	E	JENAM 500-1200 m		DEEP, SHALLOW MARINE	S SOURCE ROCKS
		LAISANG 500-2000 m		DEEP, SHALLOW MARINE & DELTA FRONT	SHALES WITHIN THE OLIGOCENE JENAM PALEOGENE DISANG FORMATIONS
EOCENE	L				
	M	DISANG 2000 m		DEEP MARINE	

Fig. 4 General stratigraphy of Tripura (Jena et al 2011)

Eaton's (1975) and Bowers (1995) methods. The first prediction approach by Hottman and Johnson (1965) method is still used in the industry due to its preciseness in pore pressure prediction. This method utilises calibrated sonic log velocities from offset well data and estimates the pore pressure for the proposed drilling location by linear regression.

Eaton's method (Eaton 1975) approximates the effective vertical stress with ratio of sonic log velocities and resistivity values (Fig. 5). The modified Eaton's equation for variable overburden gradient is

$$P_p = \sigma_{ob} - (\sigma_{ob} - P_{p \text{ normal}}) \left(\frac{v_{\text{observed}}}{v_{\text{normal}}} \right)^3 \quad (4)$$

$$P_p = \sigma_{ob} - (\sigma_{ob} - P_{p \text{ normal}}) \left(\frac{R_{\text{observed}}}{R_{\text{normal}}} \right)^{1.2} \quad (5)$$

where

$V_{\text{observed}}, R_{\text{observed}}$ = observed values of interval velocity, resistivity at the depth of interest.

$v_{\text{normal}}, R_{\text{normal}}$ = values of interval velocity, resistivity if the formation is compacted normally at the same depth.

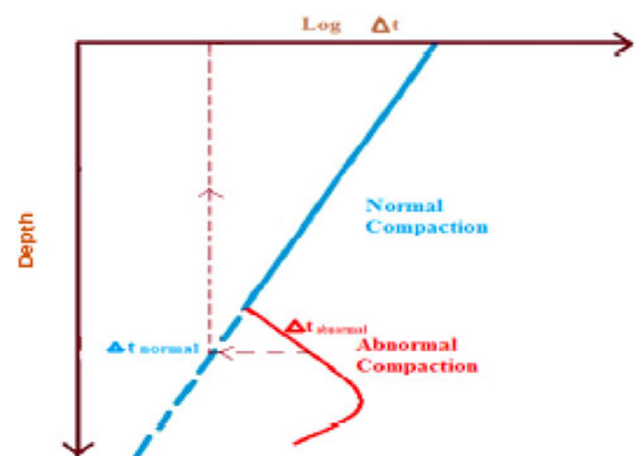


Fig. 5 Eaton's method-graphical procedure

The method applied for pore pressure prediction from the seismic velocity data is explained very systematically in Fig. 6. Two seismic sections located in the synclinal and flank part of the Atharamura anticline are considered in the paper. Total 6 CDPs are taken from the synclinal section and total 22 CDPs are taken from the flank section. Both seismic sections are oriented in the direction of west-east

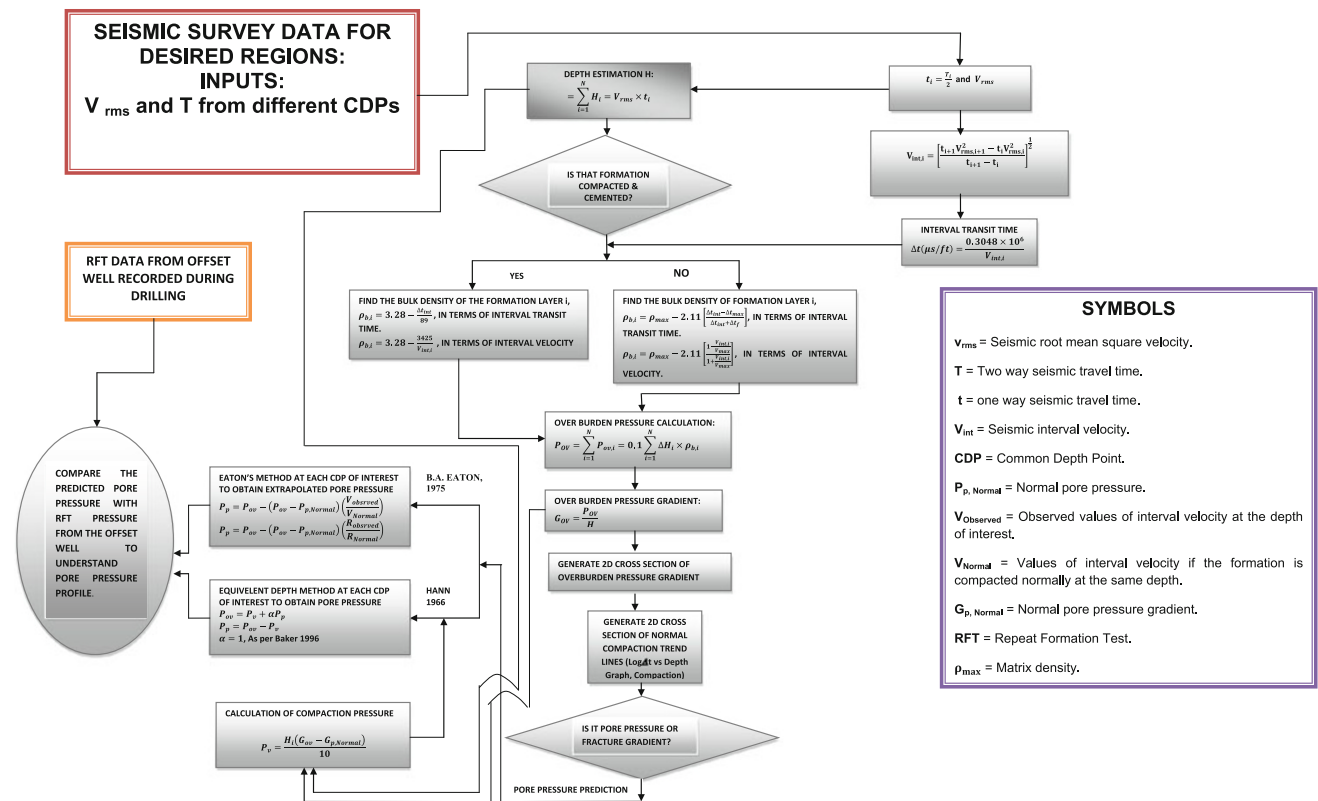


Fig. 6 Systematic workflow for pore pressure prediction from seismic interval velocity

and input data contain corrected values of two-way travel time and average (normal) velocity values for both sections. Figures 7 and 8 show the interval velocity obtained by inverting time-depth pair from seismic survey in synclinal section and flank section, respectively.

Result and discussion

In Atharamura anticline the overpressure starts in shallow depths (1,482–2,145 m) in synclinal section part while in flank part it starts deeper (2,653–5,919 m) as shown in the Table 1. The pore pressure gradient attains the maximum value of 1.03 psi/foot both in synclinal and flank sections of Atharamura anticline. Velocity reversals were frequently observed on both flank and synclinal part of Atharamura anticline (Figs. 7, 8) but we were unable to confirm the cause of fluid expansion, as the density log data are not available.

Table 1 shows that the prediction of pore pressure observed overpressured formation continues up to depth of 10,000 m, which is practically impossible as there are no sedimentary rocks that exist below the depth of 6,000 m. This is because the entire pore pressure prediction is based on the assumption that velocities have the linear relationship with depth. But this assumption is not valid at greater

depths (Aki and Richards 1980) as the linear relationship between propagation velocity and depth vanishes below 6,000 m.

The predicted pore pressure from 6 CDPs in the synclinal section and 22 CDPs from the flank section of the Atharamura anticline were compared with offset well measured pore pressures and observed an excellent match between them (Table 2). Out of 22 CDPs prediction, 3 of them show similarities with offset well measured pore pressures in flank section, and 5 CDPs prediction out of 6 show similarities with offset measured pore pressure in synclinal section. It should be stressed here that there is no accurate match but only resemblance between the predictions and measured pore pressures. This can be observed well with the help of figures shown for eight different offset wells namely AD-4 trend, Agartala Dome-6. Ambasa trend, Kathalchari trend, Kubal, Masimpur-3, Rokhia structure-RO1, and Tichna structure-TI1 (Figs. 9, 10, 11, 12, 13, 14, 15, 16). But this pressure match cannot be taken as assurance for the accuracy of the predictions. Moreover, it is not necessary for the prediction to match with pore pressure of the offset wells which are located far away from Atharamura anticline and in different geological conditions. For example, one of the offset well locations, Agartala Dome is a surface structure while Kathalchari, Tichna, Kubal wells were located in different anticlines

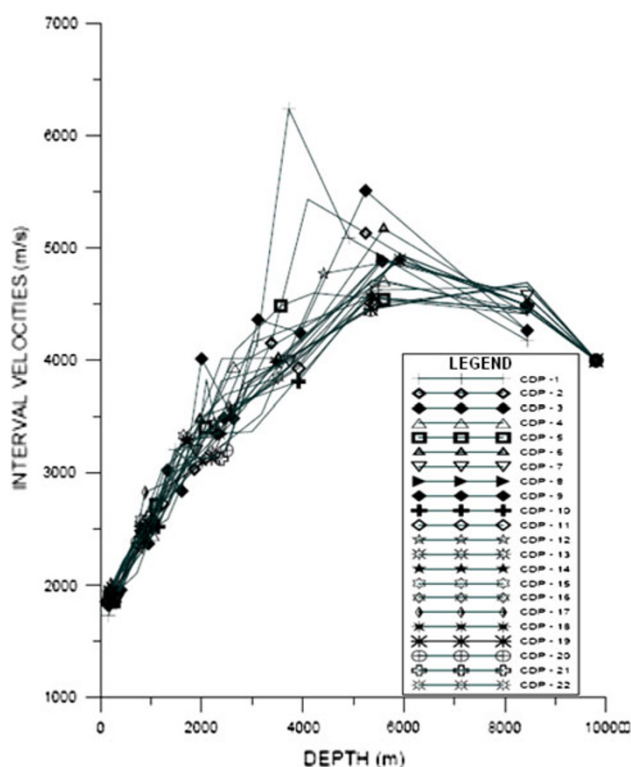


Fig. 7 Interval velocities versus depth obtained by inverting travel times recorded in the Synclinal section of Atharamura Anticline

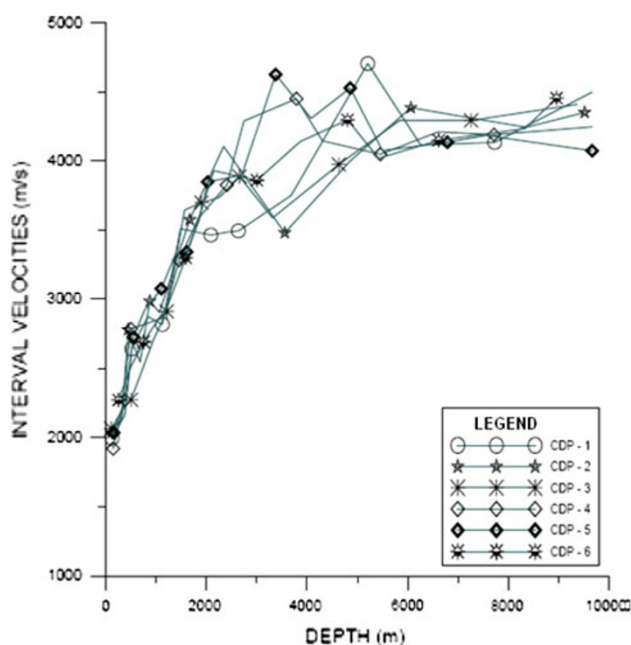


Fig. 8 Interval velocities versus depth obtained by inverting travel times recorded in the Flank section of Atharamura Anticline

exposed to the surface. But this match gave an opportunity to explore the most likely reason for the pore pressure succession in the Tripura region (Fig. 3).

Table 1 Depth range of overpressure on the Atharamura synclinal section and flank section

CDP	Synclinal section (m)	Flank section (m)
1	1,482–10,000	2,653–10,000
2	1,666–10,000	3,069–10,000
3	2,253–10,000	2,630–10,000
4	2,743–10,000	3,469–10,000
5	2,021–10,000	4,218–10,000
6	2,145–10,000	3,516–10,000
7	–	3,733–10,000
8	–	3,733–10,000
9	–	3,915–10,000
10	–	3,915–10,000
11	–	5,915–10,000
12	–	5,919–10,000
13	–	4,416–10,000
14	–	5,360–10,000
15	–	5,360–10,000
16	–	5,360–10,000
17	–	5,360–10,000
18	–	5,342–10,000
19	–	5,342–10,000
20	–	5,427–10,000
21	–	5,427–10,000
22	–	5,427–10,000

Table 2 Predicted pore pressures match with measured pore pressures from offset wells

Well name	Number of CDP points on the synclinal section showing match drilled well	Number of CDP points on the flank section showing match drilled well	Over pressure starts at (m)
AD-4 trend	2	1	3,000
Agartala Dome-6	1	2	2,500
Ambasa N trend	3	2	3,200
Kathalchari trend	3	2	2,100
Kubal	1	1	1,800
Masimpur-3	2	2	2,500
Rokhia structure-RO1	3	3	2,300
Tichna structure-TI1	3	2	2,400

Measured pore pressures of wells drilled on the top of the other anticlines match with predicted pore pressures on the flank and synclinal part of the Atharamura. This

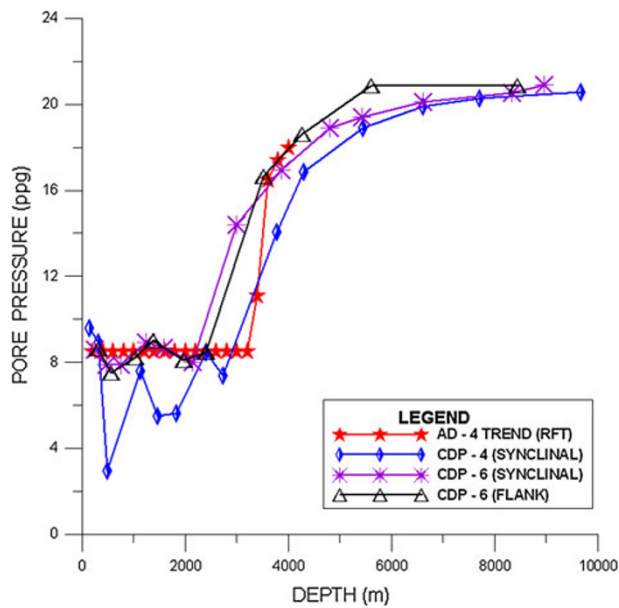


Fig. 9 AD-4 Trend measured pore pressures versus predicted pore pressures

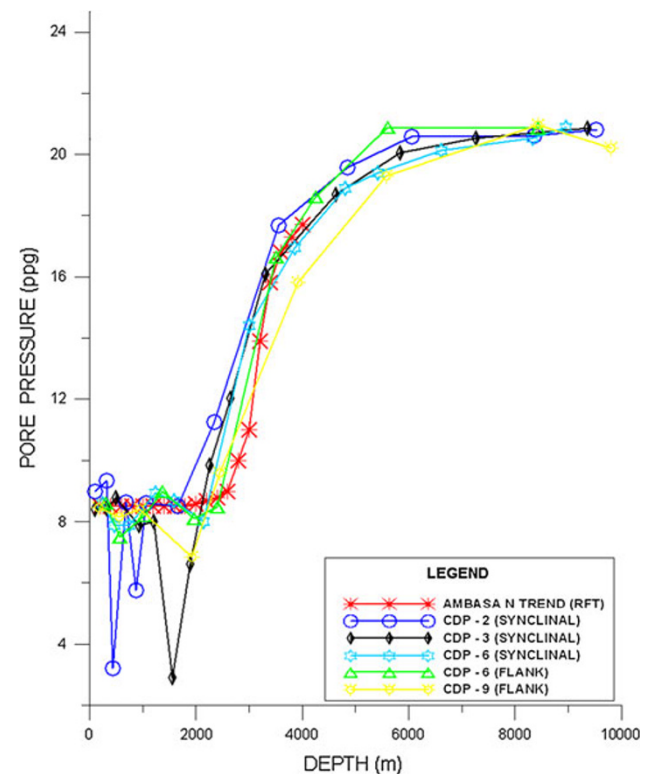


Fig. 11 Ambasa N trend measured pore pressures versus predicted pore pressures

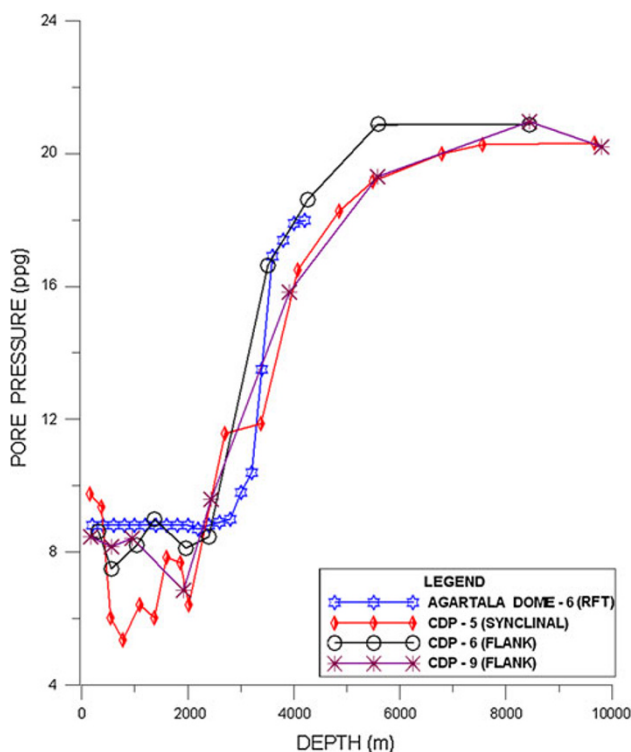


Fig. 10 Agartala Dome-6 measured pore pressures versus predicted pore pressures

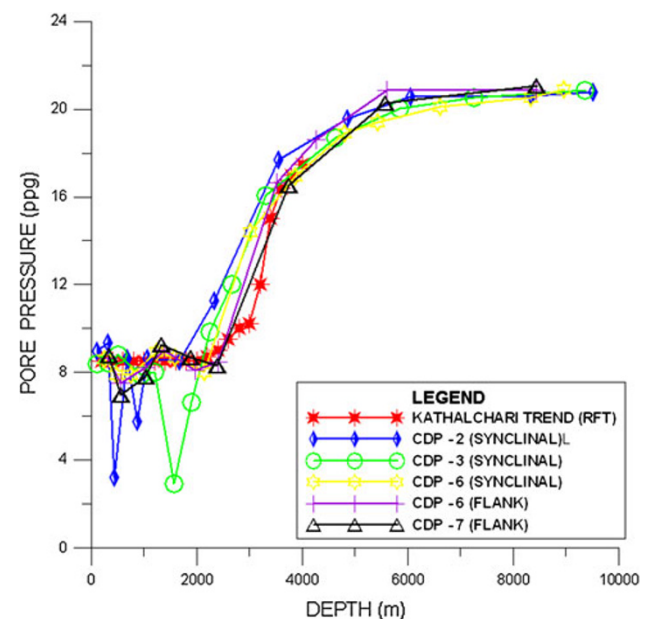


Fig. 12 Kathalchari trend measured pore pressures versus predicted pore pressures

indicates the presence of single pore pressure source in the sub-basin. As the anticlines in Tripura become steeper from west to east, the overpressure measured on the top of the other structures located in the western part matched with predicted pressure of the Atharamura structure in eastern

part. The increasing steepness from west to east could be the main reason for the overpressure migration to the greater depths in the Atharamura. Unlike in the flank and syncline part, hydrocarbon-bearing middle Bhuban

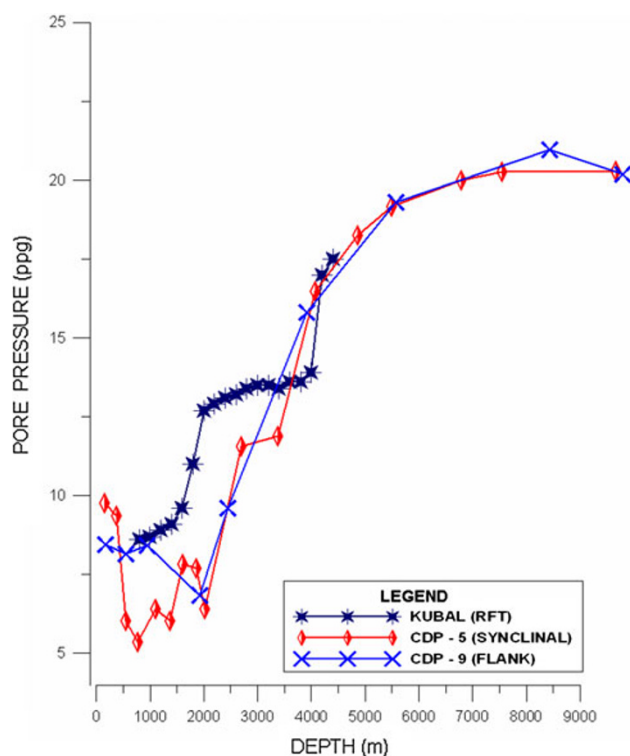


Fig. 13 Kubal measured pore pressures versus predicted pore pressures

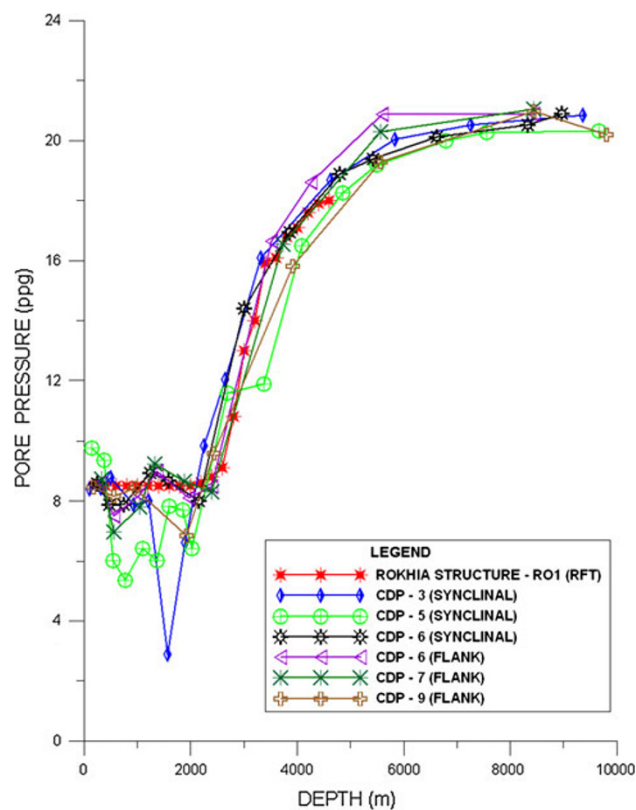


Fig. 15 Rokhia structure-RO1 measured pore pressures versus predicted pore pressures

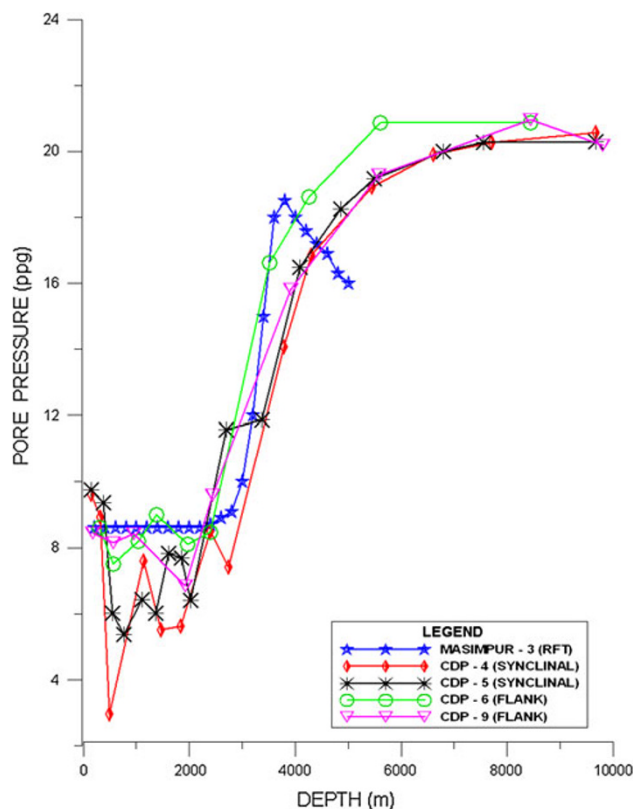


Fig. 14 Masimpur-3 measured pore pressures versus predicted pore pressures

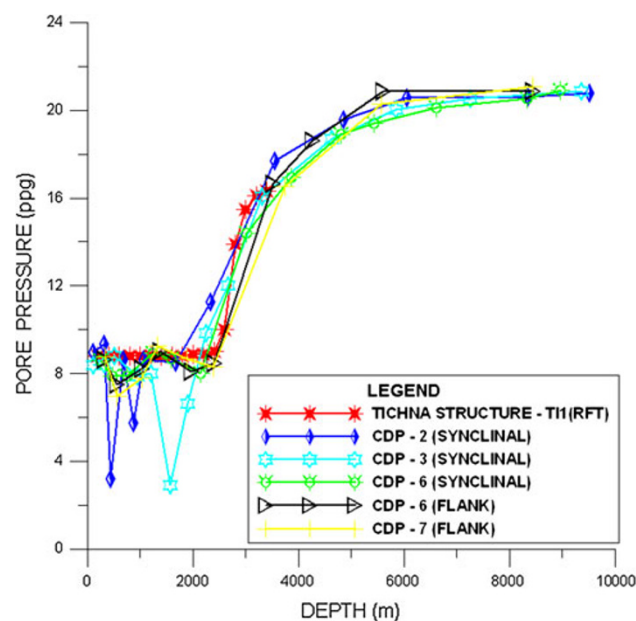


Fig. 16 Tichna structure-TI1 measured pore pressures versus predicted pore pressures

formation is exposed up to the surface on top of the Atharamura anticline. Thus, it offers the permeable flow path for pore fluids to the top of the Atharamura. If the impermeable seal is available on top of the anticline, overpressures, which are encountered at deeper depths in flank part could be expected at shallow depths on the top of the anticline.

Conclusions

- Seismic interval velocities can be used to estimate pore pressure section from surface seismic data but accurate seismic velocities are required for reliable results and offset well data for comparison. Pore pressure prediction provides critical information for the design of future wells and understanding of fluid migrations.
- Pre-drill pore pressure prediction approach requires integration of surface and borehole measurements to minimize drilling risks and reduce the cost of drilling.
- Detection of overpressured zone in the Atharamura anticline can be achieved through establishing an accurate seismic velocity-pore pressure transform. The predicted pore pressure after calibration to formation pore pressure measurements indicated different pore pressure regimes at different depths.
- Seismic velocity plateaus confirm the cause of overpressure. The main reason for this overpressure is undercompaction.
- From the comparisons with offset wells measured pore pressures it is found that the region is characterized by single pressure source and overpressures migrated to the shallow depths from west to east in the Tripura sub-basin.
- As the hydrocarbon bearing middle Bhuban formation is exposed on the top of the anticline, there is huge possibility for the presence of overpressures at the shallow depths, provided impermeable seal on the top.

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References

- Aki K, Richard PG (1980) Quantitative seismology, Freeman and Co., New York pp 385–416
- Bourgoyne AT (Jr), Millheim KK, Chenevert ME, Young FS (Jr) (1991) Applied drilling engineering, revised 2nd printing, pp 246–250
- Bowers GL (1995) Pore pressure estimation from velocity data: accounting for pore-pressure mechanisms besides undercompaction, SPE drilling and completion (June 1995) pp 89–95
- Dix CH (1955) Seismic velocities from surface measurements. *Geophysics* 20:68–86
- Domenico SN (1977) Geophysics—elastic properties of unconsolidated porous sand reservoirs, pp 1–14
- Dutta NC (1997) “Pressure prediction from seismic data: implication for seal distribution and hydrocarbon exploration and exploitation in deepwater Gulf of Mexico, NPF special publication No. 7, Elsevier, Singapore, pp 187–199
- Eaton BA (1975) “The equation for geopressure prediction from well logs. SPE 50th annual fall meeting, Dallas, September 28–October 1. SPE, Dallas, pp 2–4
- ENI SPA (1999) Overpressure evaluation manual, company manual, pp 141–170
- Ganguly S (1983) Geology and hydrocarbon prospects of tertiary succession of Tripura-Cachar-Mizoram region. *Petroleum Asia J* 1:105–109
- Hottman CE, Johnson RK (1965) Estimation of formation pressures from log-derived shale properties, JPT, pp 717–722
- Jena AK, Das NC, Saha GC, Samanta Asim (2011) Exploration in synclinal area of Tripura fold belt, India: a re-found opportunity, expanded abstract presentation at AAPG annual convention and exhibition, Houston, April 10–13
- Pennebaker (Jr) ES (1968) Seismic data indicate depth magnitude of abnormal pressures. Spring meeting of southern district, Texas, pp 184–191
- Rubey WW (1927) Effect of gravitational compaction on the structure of sedimentary rocks. *AAPG Bulletin* 11:621–632
- Sahay B, Singh OD, Rai A, Talukdar BN (1998) Occurrence of overpressures and its implications in North–East India”, SPE Oil and gas conference and exhibition, New Delhi, pp 653–667
- Swarbick Richard E, Huffman Alan R, Bowers, Glenn L (1999) Pressure regimes in sedimentary basins and their prediction, the leading edge, p 2